Colorado Procedure – Laboratory 5115a

Standard Method of Test for

Preparing and Determining the Density of Bituminous Mixture Test Specimens Compacted by the Superpave Gyratory Compactor

(This procedure is based upon AASHTO T 312-14. AASHTO T 312-14 or any subsequent revision may not be used in place of this procedure.)

1. SCOPE

1.1 This standard covers the compaction of 150 mm diameter and 100 mm diameter test specimens of hot mix asphalt (HMA) using the Superpave gyratory compactor.

1.2 The values stated in SI units are to be regarded as the standard.

1.3 This standard may involve hazardous materials, operations, and equipment. This standard does not purport to address all of the safety problems associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.

2. REFERENCED DOCUMENTS

2.1 *AASHTO Standards:*

T 312 Preparing and Determining the Density of Asphalt Mixture Specimens by Means of the Superpave Gyratory Compactor

M 231 Weighing Devices Used in the Testing of Materials

2.2 *Colorado Procedures:*

CP 44 Bulk Specific Gravity and Percent Relative Compaction of Compacted Bituminous Mixtures Using Saturated Surface-Dry Specimens

CP 51 Determining the Maximum Specific Gravity of HMA

CP-L 5101 Verification of Laboratory Equipment Used to Test Bituminous Mixtures

CP-L 5106 Resistance to Deformation of Bituminous Mixtures by Means of Hveem Apparatus

CP-L 5109 Resistance of Compacted Bituminous Mixture to Moisture Induced Damage

2.3 *Other Standards:*

ASME B46.1 Surface Texture (Surface Roughness, Waviness, and Lay)

3. SIGNIFICANCE AND USE

3.1 This standard is used to prepare specimens for determining the mechanical and volumetric properties of HMA. The specimens simulate the density, aggregate orientation, and structural characteristics obtained in the actual roadway when proper construction procedure is used in the placement of the paving mix.

3.2 This test method may be used to monitor the density of test specimens during their preparation. It may also be used for field control of an HMA production process.

NOTE 1: It is expected that the density of every specimen after gyration number 10 will approach a straight line when plotted versus the base 10 logarithm of the number of gyrations. The line will become asymptotic as it approaches 100 percent of the theoretical maximum specific gravity.

4. APPARATUS

4.1 *Superpave Gyratory Compactor* – An electrohydraulic or electromechanical compactor that conforms to AASHTO T 312, with a ram and ram heads as described in Subsection 4.2. The axis of the ram shall be perpendicular to the platen of the compactor. The ram shall apply and maintain a pressure of 600 ± 18 kPa to a specimen cross section with a diameter of 150 mm or a diameter of 100 mm (see Note 2). The compactor shall tilt specimen molds at an angle of 1.25 ± 0.02 degrees (21.8 ± 0.35 mrad) for 100

mm molds measured externally and at an angle of 1.16 ± 0.02 degrees (20.2 ± 0.35 mrad) for 150 mm molds measured internally and gyrate specimen molds at a rate of 30.0 ± 0.5 gyrations per minute throughout compaction.

NOTE 2: This stress calculates to 10600 ± 310 N total force for 150 mm specimens. This stress calculates to 4710 ± 140 N total force for 100 mm specimens.

4.1.1 *Specimen Height Measurement and Recording Device* - When specimen density is to be monitored during compaction, a means shall be provided to continuously measure and record the height of the specimen, to the nearest 0.1 mm during compaction, once per gyration.

4.1.2 *Computer, Printer, and Software* - The system may include a connected printer capable of printing test information, such as specimen height per gyration. In addition to a printer, the system may include a computer and suitable software for data acquisition and reporting.

4.2 *Ram Heads and End Plates* - Ram heads and end plates shall be fabricated from steel with a minimum Rockwell hardness of C 48. The ram heads shall stay perpendicular to their axis. The platen side of each end plate shall be flat and parallel to its face. All ram and end plate faces (the sides presented to the specimen) shall be flat to meet the smoothness requirement in Section 4.2.1 and 4.2.2. For 150 mm molds, ram and end plate faces shall have a diameter of 149.50 to 149.75 mm. For 100 mm molds, ram and end plate faces shall have a diameter of 99.60 to 99.77 mm.

4.2.1 Specimen Molds (150 mm specimens) - Specimen molds shall have steel walls that are at least 7.5 mm thick and are hardened to at least a Rockwell hardness of C 48. The inside finish of the molds shall have a root mean square (rms) of 1.60 µm or smoother (see Note 3). Molds shall have an inside diameter of 150.00 ± 0.10 mm, measured according to CP-L 5101, and be at least 250 mm in length.

4.2.2 Specimen Molds (100 mm specimens) - Specimen molds shall have steel walls that are at least 7.0 mm thick and are hardened to at least a Rockwell hardness of C 48. The inside finish of the molds shall have a root mean square (rms) of 1.60 µm or smoother (see Note 3). Molds shall have an inside diameter of 100.00 ± 0.10 mm, measured according to CP-L 5101, and be at least 250 mm in length.

NOTE 3: Smoothness measurement is in accordance with ASME B 46.1. One source to obtain these for a surface comparator, which is used to verify the rms value of 1.60 µm, is GAR Electroforming, Danbury, Connecticut.

4.3 *Wide-Mouth Funnel* - approximately 230 mm (9 in.) in diameter and 75 mm (3 in.) deep with mouth that conforms to the top inside edge of the mold.

4.4 *Thermometers* – Digital, armored, glass, or dial-type thermometers with metal stems for determining temperature of aggregates, asphalt, and asphalt mixtures between 10°C to 232°C.

4.5 *Balance* - A balance meeting the requirements of AASHTO M 231, Class G5 for determining the mass of aggregates and asphalt.

4.6 *Forced-Draft Oven* - A forced-draft oven, thermostatically controlled to ± 3°C, for heating aggregates, asphalt, and equipment as required. The oven shall be capable of maintaining the mixing and compaction temperatures specified in this procedure.

4.7 *Miscellaneous* - flat bottom metal pans for heating aggregates; scoop for batching aggregates; containers: grill-type tins, and beakers; containers for heating asphalt; large mixing spoon or small trowel; large spatula; gloves for handling hot equipment; paper disks, 150 mm diameter or 100 mm diameter depending on sample size; lubricating materials recommended by the compactor manufacturer; mechanical mixer (optional).

5. HAZARDS

5.1 Use standard safety precautions and protective clothing when handling hot paving mix and preparing test specimens.

6. CALIBRATION

6.1 The Superpave gyratory compactor requires calibration as detailed in the Manufacturer's Manual of Operation and Maintenance.

7. PREPARATION OF APPARATUS

7.1 At least 5 minutes before the paving mix is ready for placement in the mold, turn on the main power on the compactor.

7.2 For Superpave compactors, perform the

height verification as specified in the Manufacturer's Operations Manual. Verify the machine settings are correct for angle, pressure, and number of gyrations.

7.3 Verify that the automatic counter is reset and is set to shut off when the proper number of gyrations has been reached.

NOTE 4: Unless directed otherwise, the number of gyrations applied to volumetric specimens will be N(design). Hveem Stability using CP-L 5106 will be determined for specimens compacted to N(design). Specimens used for the Lottman test (CP-L 5109) are compacted until the specimen reaches a pre-determined void content.

7.4 Lubricate any bearing surfaces as needed per the manufacturer's instructions.

7.5 When specimen density / height are to be monitored, the following additional item of preparation is required. Immediately prior to the time when the paving mix is ready for placement in the mold, turn on the device for measuring and recording the height of the specimen and verify that the readout is in the proper units, mm. Verify that the recording device is ready, and, if used, prepare the computer to record the height data and enter the header information for the specimen.

8. PLANT SAMPLES

8.1 For plant-produced HMA only, a minimum of three volumetric specimens per field sample shall be compacted. To produce 100 mm volumetric specimens, split out material having a mass, in grams, equal to the multiplier from Table 1 × the Theoretical Maximum Specific Gravity (CP 51) of the material to be compacted or the Theoretical Maximum Specific Gravity from the Form #43. Other multipliers may be used that satisfy the conditions of Subsection 10.2 regarding specimen dimensions. To make 150 mm volumetric specimens, split out material having a mass, in grams, equal to 1670 × the Theoretical Maximum Specific Gravity of the material to be compacted or the Theoretical Maximum Specific Gravity from the Form #43. Before compaction, heat the specimens in a forced-draft oven, having the compaction temperature specified in Table 2, until at least 15 minutes after the specimens have been brought to compaction temperature, not to exceed 4 hours. Plant-produced material should be maintained at a temperature above 200°F for more than 1 hour after it is produced and before compaction. This may occur during the transport of the samples or during the time that the specimens are being heated before compaction. For plant produced HMA, resume the procedure at Subsection 10.3.

Table 1

Number of Gyrations	Multiplier
50	470
75	474
100	478
125	482
SMA	470

9. LABORATORY-MIXED SAMPLES

9.1 For laboratory-mixed volumetric specimens, compact at least one specimen at each of three or more different asphalt cement contents to produce specimens which span the target air void content. Weigh cumulatively into a separate pan for each test specimen the quantity of each size fraction of aggregate required to produce a batch that will result in a compacted specimen having a mass equal to the multiplier from Table 1 × the Theoretical Maximum Specific Gravity for 100 mm diameter specimens, or, having a mass of (1670 ± 4) × the Theoretical Maximum Specific Gravity for 150 mm diameter specimens. If lime is added to the dry aggregates, it shall be hydrated using the same proportion of water expected to be added during mix production. Specimens may be produced which exceed the recommended mass as long as their mass is corrected to the specified sample mass before compaction.

9.2 Place the pans and the asphalt binder container in the oven and heat to the required mixing temperature.

9.2.1 Mixing temperatures for Hveems and Lottmans are given in Table 2.

9.3 Charge the mixing bowl with the heated aggregate in one pan and mix thoroughly. Form a crater in the dry blended aggregate and weigh the required amount of asphalt binder into the mix. Immediately initiate mixing.

9.4 Every attempt should be made to minimize the amount of time that the asphalt binder is held at mixing temperature in the oven.

9.5 Mix the aggregate and asphalt binder as quickly and thoroughly as possible to yield a paving mix having a uniform distribution of

asphalt binder. As an option, mechanical mixing may be used.

9.6 After completing the mixture preparation, place the loose mix in a shallow, flat pan. Heat the mixture in a forced-draft oven at compaction temperature for not less than 2 hours and not more than 3 hours. For laboratory produced HMA, resume the procedure at Subsection 10.3.

10. COMPACTION PROCEDURE

10.1 If compacting a SMA mix, see Appendix A for special handling recommendations.

10.2 For the purposes of this Colorado Procedure, specimen diameters shall be 100 mm unless directed otherwise. Heights shall be 63.5 ± 5.0 mm for 100 mm volumetric diameter specimens and shall be 100 ± 5 mm for 150 mm diameter specimens. Specimens having heights outside this range should be discarded and new specimens compacted having masses which are corrected to yield specimen heights within this range. Laboratory-mixed specimens having heights outside this range must be discarded.

10.2.1 Lottman specimens shall have the same mass as volumetric specimens of the same diameter unless a change in mass is being used to obtain a desired void content.

10.3 Place a compaction mold and base plate in an oven at compaction temperature at least 60 minutes prior to the estimated beginning of the compaction (during the time the mixture is being conditioned).

10.4 Compaction temperatures for Hveems and Lottmans have been determined for many different sources of AC and are summarized in Table 2.

TABLE 2

Superpave Binder Grade	Lab Mixing Temp.	Lab Compaction Temp.
PG 58-28	310° F (154° C)	280° F (138° C)
PG 58-34	310° F (154° C)	280° F (138° C)
PG 64-22	325° F (163° C)	300° F (149° C)
PG 64-28	325° F (163° C)	300° F (149° C)
PG 70-28	325° F (163° C)	300° F (149° C)
PG 76-28	325° F (163° C)	300° F (149° C)

All temperatures in this table have a tolerance of ± 2.8°C (± 5°F)

10.4.1 Set the number of gyrations to N(des) for specimens being evaluated for volumetric properties and Hveem Stability (CP-L 5106). Make sure the height setting will not stop the compactor before the desired number of gyrations is applied.

10.4.2 Lottman specimens shall have the same mix compaction temperature specifications and mold temperature specifications as volumetric specimens. For Lottman specimens (CP-L 5109), enter the final sample height (corrected if necessary to achieve the desired sample air voids) into the compactor control panel. Variations in sample heights, which result in Lottman specimens having 7 ± 1 percent air voids, are permitted.

10.4.2.1 The suggested calculation to determine Lottman height is as follows:

$$\frac{\textbf{(Ave. Bulk SpG @ N(des) x Ave. Ht. @ N(des)}}{\textbf{(0.925 x Rice)}}$$

10.5 When the compaction temperature is achieved, remove the heated mold and base plate from the oven and place them on a non-metallic surface. Place a paper disk on the bottom of the mold. Place the wide-mouth funnel onto the top of the mold. The time the mold is out of the oven should be minimized as much as possible.

10.6 Stir the mixture only as necessary to reduce segregation and place the mixture into the mold in one lift. Care should be taken to avoid segregation in the mold. Segregation may be determined by examining the compacted specimen. The entire surface of non-segregated specimens will have a uniform texture. After all the mix is in the mold, level the mix if necessary

and place another paper disk on top of the material. Any handling of the mix (including leveling) after loading should be minimized to the greatest practical extent.

10.7 Load the specimen mold with paving mix into the compactor and center the loading ram.

10.8 Press the start button and lower the ram until the pressure on the specimen reaches 600 kPa ± 18 kPa. The time taken between removing the sample from the oven until the START button is pressed should be no more than 60 seconds.

10.9 Apply a 1.25 ± 0.02 degrees (21.8 ± 0.35 mrad) angle tilt for 100 mm molds measured externally and an angle of 1.16 ± 0.02 degrees (20.2 ± 0.35 mrad) for 150 mm molds measured internally to the mold assembly and begin the gyratory compaction.

10.10 Allow the compaction to proceed until the desired number of gyrations is reached and the gyratory mechanism shuts off.

10.11 Remove the mold from the compactor, and extrude the specimen from the mold.

NOTE 5: Extrusion can be accomplished immediately for most HMA paving mixes. For lean, rich, or tender mixtures, a cooling period of 5 to 10 minutes in front of a fan may be necessary before extruding the specimen.

10.12 Remove the paper disks from the top and bottom of the specimens.

NOTE 6: Before reusing the mold, place it in an oven at compaction temperature for at least 15 minutes. The use of multiple molds will speed up the compaction process. It is recommended that a minimum of 3 molds be used to assure that 15 minutes between usages is achieved.

11. DENSITY PROCEDURE

11.1 The following steps are required in addition to those specified in Section 8, 9, and 10.

11.1.1 Determine the maximum specific gravity (G_{mm}) of the loose mix, in accordance with CP 51, using a companion sample.

11.1.2 Use the compactor's output to record the specimen height to the nearest 0.1 mm after each revolution.

11.1.3 Record the mass of the extruded specimen to the nearest 0.1 gram and determine the bulk specific gravity (G_{mb}) of the extruded specimen in accordance with CP 44.

12. DENSITY CALCULATIONS

12.1 At the completion of the bulk specific gravity test, the percent compaction at various numbers of gyrations can be determined as follows:

$$C_x = \frac{G_{mb} h_m}{G_{mm} h_x} \times 100$$

Where:

C_x = Corrected relative density at "x" gyrations expressed as a percentage of the Maximum Theoretical Specific Gravity,
G_{mb} = Measured bulk specific gravity of the extruded specimen,
G_{mm} = Theoretical Maximum Specific Gravity of the mix,
h_m = Measured height in millimeters of the specimen reported by the Superpave compactor at the final gyration,
h_x = Height in millimeters of the specimen after "x" gyrations.

12.2 Determine the bulk specific gravity of specimens at various numbers of gyrations as follows:

$$G_{mbx} = \frac{G_{mbf} h_m}{h_x}$$

Where:

G_{mbx} = Bulk specific gravity of the specimen after "x" gyrations,
G_{mbf} = Measured bulk specific gravity of the extruded specimen,
h_m = Measured height in millimeters of the specimen reported by the Superpave compactor at the final gyration,
h_x = Height in millimeters of the specimen after "x" gyrations.

12.3 Determine the percent air voids at various numbers of gyrations (P_{ax}) as follows:

$$P_{ax} = 100 - C_x$$

Where:

P_{ax} = Percent air voids of specimen after "x" gyrations.

13. REPORT

13.1 There is no designated CDOT Form used for recording / reporting information for this CP-L.

13.2 The report should include the following items or allow the following items to be calculated.

13.3 Project name.

13.4 Specimen identification.

13.5 Date of test reporting.

13.6 Percent binder in specimen, to nearest 0.1 percent.

13.7 Nominal diameter of the mold used (d).

13.8 Number of gyrations used to compact specimen.

13.9 Maximum specific gravity (G_{mm}) of the specimen by CP 51, to nearest 0.001.

13.10 Bulk specific gravity (G_{mb}) of the compacted specimen by CP 44, nearest 0.001.

13.11 Height of the specimen after selected gyrations (h_x), nearest 0.1 mm.

13.12 Relative density (C_x) expressed as a percent of the air voids of the compacted specimen, to nearest 0.1 percent.

13.13 Hveem Stability to nearest whole number.

14. PRECISION AND BIAS

14.1 Precision - The results of two properly conducted tests on the same material, by the same operator, using the same equipment, should be considered suspect if the bulk specific gravities differ by more than 0.020. When three replicate specimens are analyzed, and one of the three results differs from the average by more than 0.011, exclude that single result from the reported average. If the remaining two results differ by more than 0.020, complete retesting is required. Such occurrence that differs by more than the maximum allowable range is a warning that there may have been some error in the test procedure, or some departure from the prescribed conditions of the test on which the limits appearing in the test method are based.

14.2 Bias - A bias for this test method will be determined at a later date, and included in future revisions.

Appendix A, CP-L 5115

Special Handling Recommendations for SMA Mixes

Perform the following steps when handling laboratory-produced mix sample material.

(1) Set up individual sample without mineral filler.

(2) Stir set-up dry and then mix with 3% water (without mineral filler).

(3) Heat both set-up and mineral filler to required mixing temperature (325°F for PG 76-28).

(4) Mix set-up by hand with enough asphalt cement to accommodate both the set-up and the mineral filler.

(5) Blend proper amount of hot mineral filler to premixed set-up.

(6) Heat for 2 hours at compaction temperature. Excessive heating time or temperature appears to increase drain down.

(7) Stir mortar back into set-up if there is any drain down.

(8) Compact to 100 gyrations.

(9) Set oven temperatures either 1°C or 2°F higher than specified for compaction. (**Note:** To ensure repeatability, it is very important to compact these samples at the specified temperature). By heating samples 1°C above the specified temperature and transferring the set-up and starting compaction as fast as possible without spilling, (approximately 45 seconds from oven to the start of compaction), the sample is compacted at the proper temperature. Individual labs should check the cooling rate of samples using their mode of sample preparation to ensure the mix is at the proper temperature during compaction.

Perform the following steps when handling project-produced mix sample material.

(1) If possible, split out samples to the test size for compaction and Rice specific gravity determination at the mixing plant immediately after sampling. The samples should then be mixed as required to reintroduce drained asphalt cement after heating for the proper time at the compaction temperature.

(2) (Optional) To prepare a can which has cooled, remove the lid, place upside down on a large pan (24"x 24"), heat for 3 hours at 300°F. This should keep any drain down in the set-up pan, instead of the bottom of the sample can.

(3) Prior to compaction be sure to scrape the pan bottom and stir mortar back into the mix before loading the mold. Spray all utensils with release agent to prevent SMA from sticking to utensils.

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